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SASTT TECHNICAL STANDARD

Trenchless construction works

Part TT4: Cured in place pipe lining of underground gravity pipelines

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Table of changes

Change No.	Date	Scope

Acknowledgement

SMEC South Africa (Pty) Ltd was appointed by the Southern African Society for Trenchless Technology (SASTT) to prepare this standard for the trenchless rehabilitation of underground gravity pipelines by means of cured-in place-pipe (CIPP) lining. The standard was prepared by Mike King of SMEC South Africa and independently reviewed by Alaster Goyns of PIPES.

The standard is being posted on the SASTT website. Any comments will be put on record and these incorporated in future editions of this document.

Foreword

This SASTT technical standard was approved by the Board of SASTT on 5 October 2021.

This document was published on 15 October 2021 and posted on the SASTT website.

SASTT-TS standards consist of a number of parts in various stages of preparation, under the general title *Trenchless construction works*.

Annex A forms an integral part of this document. Annexes B and C are for information only.

Introduction

The different parts of SASTT-TS each address a specific category of trenchless construction works. The prime purpose of the production of these standards is to create a set of standards that are generally applicable to trenchless construction works and which can be readily modified so that they are applicable to developments in existing techniques or development of new techniques for trenchless works.

The SANS 2001 and SASTT-TS family of standards provides technical descriptions of the material and workmanship standards required in the execution or performance of the works when completed (or both). These standards do not make reference to the actions of those responsible for executing the works or the parties to a contract, i.e. to the constraints relating to the manner in which the construction is to be performed. Neither do they deal with the commercial arrangements of such contracts. These standards are suitable for use in any “in-house” construction work or in any engineering and construction works contracts, for example; design by employer; design and build; develop and construct construction management or management contracts.

Standard requirements pertaining to the manner in which works are constructed can be found in the SANS 1921 family of standards.

Attention is drawn to the possibility that certain content in this document might be the subject of patent rights. SASTT shall not be held responsible for identifying any or all such patent rights.

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Contents

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Trenchless construction works

Part TT4:
Cured in place pipe lining of underground gravity pipelines

1 Scope

1.1 General

This cured in place pipe (CIPP) lining standard specification covers the rehabilitation of underground gravity pipelines by the installation of thermosetting resin liners. The scope is limited to non-pressure pipelines that flow by gravity (sewer and stormwater pipelines). The liner fabric tube can be woven, nonwoven and/or fibreglass reinforced. The resins are typically unsaturated isophthalic polyester but can be vinyl ester or epoxy resins. The flexible resin-impregnated tube is pulled or inverted into the pipeline and pressurised. The liner is then cured using the ambient air temperature, steam, circulating hot water or ultraviolet lights. The final product is a strong continuous liner with a smooth surface fitting tightly within the existing pipe. The liner extends the full length between manholes providing a continuous, structurally sound, jointless, watertight and tightfitting new pipe within a pipe.

Unsaturated isophthalic polyester resin is cost-effective, reliable, durable and has a proven track record over 4 decades. It is most commonly used for typical sewer and stormwater applications. Vinyl ester resin is used for pressure, industrial or special waste applications. Resins are chosen based on economics, chemical resistance, strength and potable water suitability.

Cured in place pipe liners protect the host pipe from further deterioration due to corrosion, erosion or loss of bedding caused by infiltration and exfiltration. The liners can stop infiltration and thereby reduce flow volumes into the pipeline system. Once installed the liners are structural and the pipeline can be considered as equivalent to a new pipeline.

The liners thicknesses are structurally designed for the physical characteristics of the existing pipe, the structural properties of the liner material and the loading conditions. The finished product is tested for conformity with the design wall thickness, diameter and the lining material structural properties.

CIPP is a trenchless technique to rehabilitate underground pipes with minimal excavations. It can be applied to pipes under roads, railways, structures, watercourses, landscaped areas, wetlands and other environmentally sensitive areas, without disturbing the surface, affecting other services, interfering with the normal flow of traffic or negatively impacting on the environment.

This standard has been prepared to cover the installation of all CIPP liners in sizes of pipes from 100 mm to 1200 mm diameter and larger. The larger the diameter, the greater are the logistical requirements for manufacture, transport, impregnation, insertion and curing of the bigger and heavier liners, together with associated risks.

1.2 Typical installations

CIPP liners can be categorised by the

curing method;
- Hot water
- Steam
- Ambient air temperature
- Ultraviolet lights

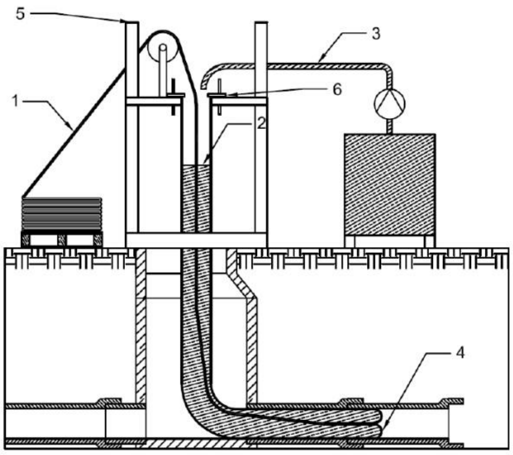
installation method
- Inverted into place with a hydrostatic head or air pressure
- Pulled into place

liner reinforcement
- Unreinforced (felt)
- Reinforced (glassfibre)

The following are illustrations of common combinations of the above that are found in practice.

a) Unreinforced liner inverted and cured with hot water

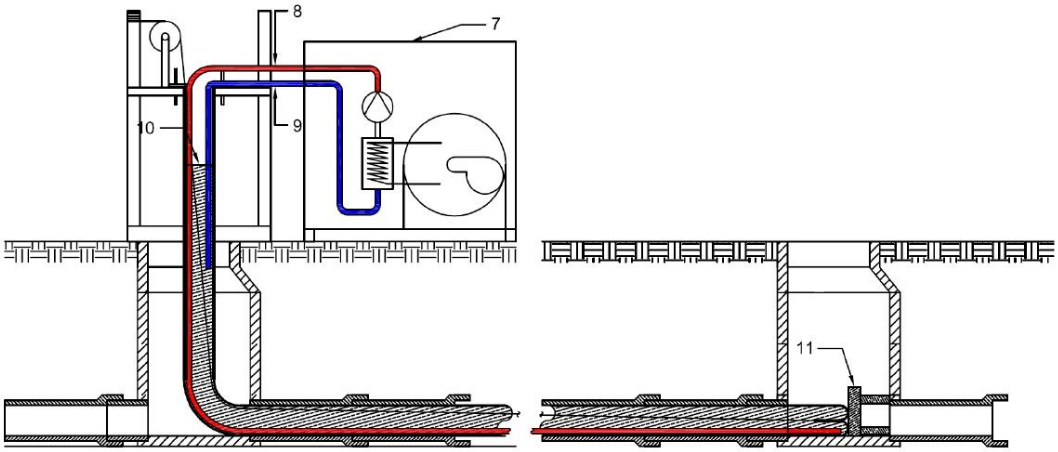
A felt liner (without reinforcement referred to as an unreinforced liner) with only an outer membrane, that is impregnated with resin (usually unsaturated isophthalic polyester resin), is pulled through rollers to achieve the required thickness and installed by inversion with a water tower and then cured with circulating hot water. Since the liner turns inside out, the resin itself will end up against the host pipe wall, and a preliner is often used.



KEY

1. Impregnated liner
2. Inversion water column
3. Water supply
4. Inversion face
5. Scaffold tower
6. Clamping collar
7. Water heater and pump
8. Hot water inflow
9. Hot water return
10. Curing water column
11. End brace

Step 1 Liner inversion

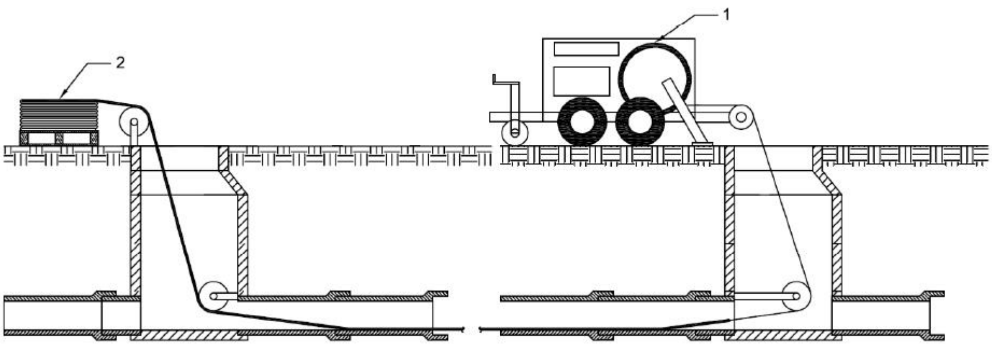


Step 2 Liner curing

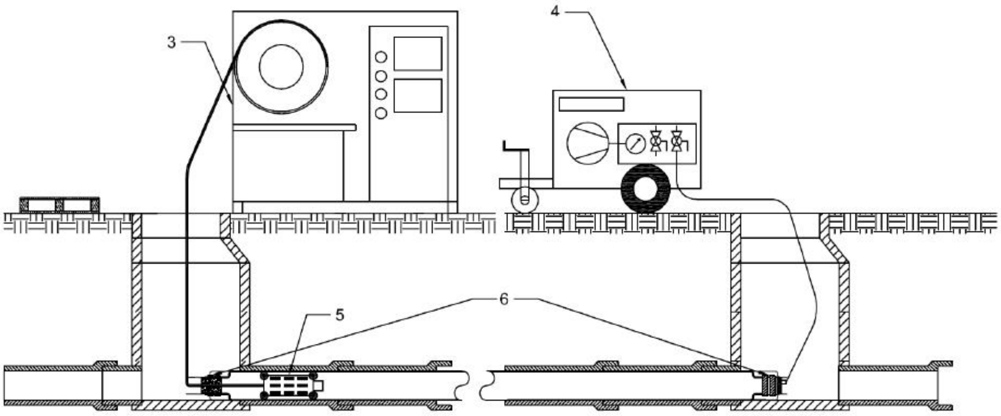
Figure 1 Liner inversion and hot water curing

b) Reinforced liner pulled in and cured with ultraviolet lights

A liner, which includes fibreglass, (referred to as a reinforced liner) with both an inner and outer membrane, fabricated and impregnated with UV activated unsaturated isophthalic polyester resin by the manufacturer, installed by being pulled into the pipe usually on a plastic sliding foil, then inflated with air and cured by pulling a train of ultraviolet lights through the pipeline.



Step 1 Liner pulled in



Step 2 Liner curing

KEY
1. Winch
2. Impregnated liner
3. Curing equipment controls and winch
4. Compressor
5. UV light train
6. Sealing end packers

Figure 2 Liner pulled in and cured with ultraviolet lights

c) Ambient curing

A third approach to curing is to use a resin that cures in the ambient air temperature without heat being applied. Once the catalyst is added to the resin the curing commences and the liner must be impregnated and installed into position promptly. The liner may be inverted or pulled into place. Calibration hoses are typically used.

d) Steam curing

Some thermosetting resins can be cured by applying controlled steam. After insertion and pressurisation, suitable steam generating equipment is required to distribute steam throughout the liner raising the temperature to effect the cure of the liner.

1.3 Specialised applications

This standard is intended for the lining of underground gravity pipelines between manholes, it should not be applied to specialised CIPP applications that include:

a) CIPP short repair lining - the lining of short lengths of pipeline using an inflatable bladder.

b) CIPP lateral lining - lining of lateral sewer connections from properties to the main sewer, including the junction.

c) CIPP lining of piping in buildings – the lining of sewer, stormwater and water services inside and under buildings.

d) Pressurised pipelines and watermains.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies. Information on currently valid national and international standards can be obtained from Standards South Africa.

American Society for Testing and Materials

ASTM F1216 *Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube*

ASTM F1743 *Standard Practice for Rehabilitation of Existing Pipelines and Conduits by Pulled-in-Place Installation of Cured-in-Place Thermosetting Resin Pipe (CIPP)*

ASTM F2019 *Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Pulled in Place Installation of Glass Reinforced Plastic (GRP) Cured-in-Place Thermosetting Resin Pipe (CIPP)*

ASTM D5813 *Standard Specification for Cured-In-Place Thermosetting Resin Sewer Piping Systems*

ASTM D638 *Standard Test Method for Tensile Strength of Plastics*

ASTM D790 *Standard Test Methods for Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials*

ASTM D2990 *Standard Test Methods for Tensile, Compressive, Flexural Creep and Creep-Rupture of Plastics*

ASTM D3567 *Standard Practice for Determining Dimensions of "Fiberglass" (Glass-Fibre-Reinforced Thermosetting Resin) Pipe and Fittings*

South African National Standards

SANS 1200, *Standardized Specification for Civil Engineering Construction.*

SANS 2001, *Construction works.*

SANS 1921, *Construction and management requirements for works contracts*

SANS 10403, *Formatting and compilation of construction procurement documents.*

3 Definitions

For the purposes of this document, the definitions given in SANS 10403 and the following additional definitions apply:

calibration hose
an impermeable tube which is inserted inside an already inserted CIPP tube, pressurised to make the liner a tight fit against the host pipe wall until the resin is cured with air, steam or ultraviolet light.

catalysed resin
resin that has been mixed with its catalyst or hardener.

CCTV inspections
inspections using closed circuit television cameras to carry out internal inspections of pipelines with appropriate transport and lighting mechanisms to view the internal surfaces.

CIPP Contractor
the CIPP Contractor is the specialist entity (contractor, subcontractor or in-house team) engaged by the Owner to implement the CIPP lining.

CIPP Designer
the CIPP Designer who is the specialist (consultant, subconsultant, in-house designer) engaged by the Owner to be responsible for the CIPP design.

Cured in place pipe (CIPP) liner
a fabric tube of woven and/or nonwoven material with or without fibreglass reinforcement, impregnated with thermosetting resin and cured to fit tightly within an existing pipe. Plastic inner and outer membranes (coatings/foils) may be included. The liner is formed within an existing pipe and takes the shape of and fits tightly in the pipe.

curing
the process of resin polymerisation, which may be initiated or accelerated by the use of heat or light.

declared value
a design parameter or a CIPP liner property that is declared in advance of the installation (by the CIPP Designer or CIPP Contractor).

delamination
a separation of the layers in the cured CIPP wall.

design wall thickness
the CIPP liner wall thickness determined by the structural design, agreed and made a declared value by the CIPP Designer and CIPP Contractor and substantiated by testing of the completed liner.

design structural properties
the structural properties of the liner, declared by the CIPP Contractor and used to calculate the design wall thickness and substantiated by testing the completed liner.

dry spot
an area of fabric in the CIPP wall which is deficient or devoid of resin.

fabric tube
a flexible tube of one or more layers of absorbent, woven or nonwoven felt fabric, felt/fibreglass or fibreglass, with or without inner or outer membranes (coatings/foils), capable of being saturated with and holding the resin during the installation and curing process.

filler
an additive which alters the thixotropic or physical properties of a resin.

host pipe
the existing pipe that is to be rehabilitated with a pipe liner.

hydrophilic rubber seals
if required in the specification data, are installed at the host pipeline ends and through which the CIPP liner is installed and cured. The seals are held in place with stainless steel retaining rings during the liner installation. Subsequently the rubber seals absorb water and swell, filling and sealing the annulus.

informative
a supplement that provides additional information intended to assist the understanding or use of the document.

inversion
the process of using a hydrostatic head of water or air pressure to turn a resin impregnated (or calibration) tube inside out and insert itself into position and tightly against the internal host pipe wall.

lift
a cured portion of CIPP that has pulled away from the existing pipe wall.

membranes
impermeable plastic inner or outer membrane tubes (coatings/foils) that are integral to the fabric tube and encompass the resin in the impregnated fabric.

normative
that with which it is necessary to conform in order to be able to claim compliance with the standard.

ovality
the ovality of circular pipe that has been distorted into an oval shape is determined by the formula ovality (%) = 100 x (maximum diameter – minimum diameter) / (maximum diameter + minimum diameter).

overpumping
the transportation of the pipeline flow around a specific section of pipeline that is being rehabilitated, comprising pumps and bypass pipelines.

Owner
the organisation that owns the pipeline that is being rehabilitated.

preliner
a thin protective polyethylene film tube inserted into the pipe to form a barrier between the host pipe and the liner.

reinforced liner
a liner that includes fibreglass to increase strength.

resin
a chemically resistant isophthalic based polyester, or vinyl ester thermoset resin and catalyst system or an epoxy resin and hardener, including curing agents and any fillers or extenders.

sliding foil
a long plastic strip that is placed in the bottom of the existing pipe to reduce friction and protect the CIPP liner when being pulled in.

specification data
is data, provisions and variations that make this standard applicable to a particular contract or works.

suitable
is capable of fulfilling or having fulfilled the intended function or fit for its intended purpose.

unreinforced liner
a liner that contains felt without any fibreglass reinforcement.

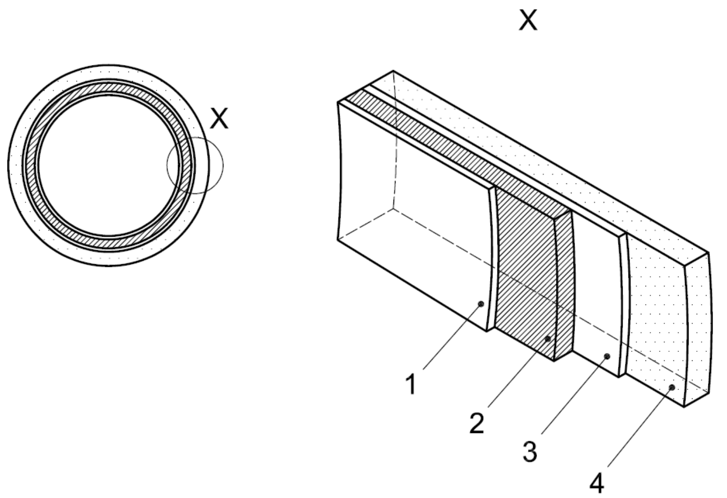
wetting out
refers to the impregnation of the fabric tube with catalysed resin.

4 Requirements

4.1 Materials

4.1.1 Fabric tube

The fabric tube is a flexible tube of one or more layers of absorbent, woven or nonwoven felt fabric, felt/fibreglass or fibreglass, with or without inner or outer membranes (coatings/foils), capable of being saturated with and holding the resin during the installation and curing process. The inner membrane may be a calibration hose which is removed after the liner has cured. (See Figure 3).



Key

1 internal or temporary membrane
2 composite (resin in carrier material/reinforcement)
3 external membrane
4 existing pipeline

Figure 3 Typical wall construction of fabric tube

The felt fabric shall be of polymeric fibres (polyamide, polyacrylonitrile, polyethylene, polyethylene terephthalate or polypropylene).

Longitudinal and circumferential joints between multiple layers of a tube should be staggered to not overlap. Seams in the fabric tube shall be stronger than the un-seamed tube.

The tube shall be fabricated to fit its final in-place position in and length of the original pipe, with allowance for stretch as recommended by the fabric tube manufacturer and be able to meet or exceed the design wall thickness.

The fabric hose shall be of sufficient strength and dimensional stability, to withstand installation forces and pressures.

Particular requirements of the fabric tube shall be stated in the specification data.

4.1.2 Preliner

A preliner is a thin protective polyethylene film tube (approx. 200 um). It is pulled or inverted into the host pipe prior to the liner installation in order to form a barrier between the host pipe wall and an inverted liner to prevent the resin from having direct contact with the host pipe. It also prevents styrene odours from entering connections.

Preliners are also used to protect liners in badly damaged pipes, where there is groundwater infiltration or where there is standing water in the pipe invert. The preliner is sized to fit tightly inside the host pipe.

Preliners are not usually used for pulled in liners commonly associated with ambient cured liners.

If required in the specification data, a preliner shall be supplied and installed as part of the liner installation process.

4.1.3 Sliding foil

A sliding foil is a long plastic strip that is placed in the bottom of the existing pipe to reduce friction and protect the CIPP liner when being pulled in. It shall cover the lower third or up to half the circumference of the host pipe. The sliding foil shall be manufactured for the purpose and/or in accordance with the specification data.

4.1.4 Calibration hose

If required in the specification data, a calibration hose shall be supplied and used in the installation of the liner.

A calibration hose is an impermeable tube which is introduced inside an already inserted CIPP tube, pressurised to make the liner a tight fit against the host pipe wall until the resin is cured with air, steam or ultraviolet light. It is usually removed after curing but can be designed to form an integral part of the liner.

Calibration hoses are typically used with ambient curing liners.

A calibration hose can also be used to install liners from a single access point.

The hose can be of reinforced PVC, silicon rubber, polyester, or high strength nylon fibre grid composite material which is assembled by slitting and heat welding the material to the required diameter of the liner to be installed.

Calibration hoses can be either pulled or inverted into the liner to provide a watertight barrier capable of withstanding the installation pressure and temperatures required to cure the liner. Calibration hoses help ensure the best possible liner finish.

4.1.5 Resins

The thermosetting resin system shall be corrosion and chemical resistant, unsaturated isophthalic polyester or vinyl ester resin and catalyst system, or an epoxy resin and hardener system, which when cured shall form a hard impermeable material.

The resin and catalyst (cure initiator) mix ratio is crucial to produce the required strength and chemical resistance of the liner. The catalyst (or hardener) is required to start the curing process of transforming the liquid resin into a thermoset solid. The resin and catalyst mix affects the strength, chemical and corrosion resistance, the resin liquid properties (for impregnation and distribution of the resin), the curing rate, the storage life and the catalysed life (pot life).

Catalysed resin will cure when exposed to heat in the case of thermal curing resins and light in the case of UV curing resins. The application of refrigeration or lightproofing, is extremely important to delay the onset of the curing process.

The resins may be thermal, ambient or ultraviolet (UV) light curing. (The specification data could modify the UV curing parts of this standard to apply to new resins that cure using blue light).

The resins shall be able to cure in the presence of water or shall be contained within impermeable flexible membranes.

Polyester and vinyl ester resins are dissolved in styrene to increase viscosity and assist in the polymerisation. Thickening agents, low profile additives, inert and reinforcing fillers are added to modify performance and initiators (photo initiators for UV curing), accelerators, inhibitors and other additives may be added to control the reaction.

The resin manufacturer shall give written confirmation of its suitability for application to inverted and pulled-in CIPP liners, stating physical properties, mixing instructions, curing process and additives used.

Particular requirements of the resins shall be stated in the specification data.

4.1.6 Styrene

Polyester and vinyl ester resins are dissolved in styrene to increase viscosity and assist in the polymerisation. Styrene has a distinctive overwhelming odour, can be detected at low concentrations and is weakly toxic. The Hazardous Substances Regulations of the Occupational Health and Safety Act, stipulate the occupational 8 hour and short term exposure limits for styrene. Work areas must be well ventilated and good housekeeping practiced on the project and installation site.

Styrene odours should be minimised to avoid creating a nuisance to residents. This can be caused by release of odours into the open air or via sewer connections that vent into properties. The impact of styrene concentrations in the process water when discharged directly into a sewer collection system is insignificant, provided the water is at ambient temperature. In addition, the styrene concentration must be less than 25 ppm when discharging into stormwater systems.

4.1.7 Lubricants

Any lubricant used to reduce friction during installation shall be non-toxic, oil-based and shall have no detrimental effect on the liner, the host pipe, the boiler or the environment.

4.1.8 Hydrophilic seals

Hydrophilic seals are used inside the ends of the host pipe to provide a seal between the host pipe and the outside of the cured liner to prevent groundwater from draining along the annulus between the liner and host pipe and discharging into the pipe system. Where high water tables and host pipe leakage occurs, hydrophilic seals may be required in the specification data.

4.1.9 Cured liner

4.1.9.1 Liner wall thickness design

The liner wall thickness shall be designed in accordance with ASTM F1216 Appendix X1- Design Considerations.

The CIPP Designer shall specify the following design parameters:

1. Gravity pipe or pressure pipe.
2. Partially or fully deteriorated design condition.
3. Host pipe internal diameter.
4. Height of water table above the pipe invert.
5. Ovality or ovality reduction factor.
6. Poisson's ratio.
7. Enhancement factor (K).
8. Factor of safety.
9. The long term creep retention factor (50 year extrapolated) to be applied to the short term flexural modulus to get a long term flexural modulus, where it is not known.
10. Similarly, the long term creep retention factor to be applied to the short term flexural strength to get a long term flexural strength, where it is not known.

Plus, in the case of a fully deteriorated design condition.

11. Soil density.
12. Live load.
13. Height of water above top of pipe.
14. Height of soil above top of pipe.
15. Water buoyancy factor.
16. Coefficient of elastic support.
17. Modulus of soil reaction.

The CIPP Contractor shall state the structural properties of the proposed liner that shall be used for the design of the liner wall thickness.

The CIPP Contractor may state structural properties less than those stated by the liner and resin manufacturers, to cover construction risks. The structural properties stated by the manufacturers are often laboratory results, whereas field results might be lower and more applicable for design.

The CIPP Contractor shall submit certificates stating the structural properties of the liner.

The short term structural properties of liners shall not be less than:

Property	Test method	Unreinforced liner minimum value	Reinforced liner minimum value
Flexural Modulus	D790	1724 MPa	5000 MPa
Flexural Strength	D790	31 MPa	45 MPa

The design wall thickness shall not be less than 1% of the liner outside diameter.

The application of the formulae in the accordance with ASTM F1216 Appendix X1, with the design parameters specified by the CIPP Designer and the design structural properties stated by the CIPP Contractor will result in a minimum design wall thickness for the liner. The CIPP Contractor may choose the next thicker liner from the manufacturer's catalogue of available sizes.

Note that the wall thickness of the liner shall exclude any plastic coatings or membranes.

On conclusion of the design of the liner wall thickness, the CIPP Designer's design parameters, the CIPP Contractor's structural design properties and the resultant design wall thickness shall be agreed to be the declared values. The cured liner shall be tested to confirm that it meets the declared structural design properties and the declared liner wall thickness and outside diameter.

4.1.9.2 Cured liner properties

The cured liner shall have the declared wall thickness, diameter and structural properties.

For inspection purposes the cured liner shall be a light colour.

4.1.9.3 Corrosion resistance

The installed and cured liner shall be able to withstand corrosion due to internal exposure to normal domestic sewage (wastewater) liquids, gasses (hydrogen sulphide, carbon monoxide, carbon dioxide and methane) as well as acids such as sulphuric acid that may condense on the liner wall. In addition, the liner must withstand any external exposure to corrosive soils or water in the surrounding soil.

The specification data may prescribe any other specific corrosion resistance that the liner must withstand.

The resin manufacturer shall give written confirmation of its suitability for application in sewers and provide certified test results.

In considering the ability of the liner to withstand corrosion, the protection of any membranes shall be ignored, and any testing shall be performed on the cured liner without membranes.

The specification data may stipulate what corrosion or chemical resistance tests must be performed on the liner (typically ASTM F1216 Appendix X2 or ASTM F1743 Section 7.2).

4.2 Plant

4.2.1 General

Suitable plant and equipment shall be provided and shall comprise liner impregnation equipment, liner handling equipment, insertion equipment, pressurisation equipment and curing equipment.

Trained and competent personnel shall operate the plant and equipment.

All equipment shall be in a good and safe operating condition with sufficient fuel, supplies, materials and spare parts on hand to maintain the system in good working order for the duration of the work.

Figures 1 and 2 illustrate the equipment in position.

4.2.2 Impregnation equipment

4.2.2.1 Thermal cured liner impregnation

A wet-out table is normally used to impregnate thermal cured liners, which can be unreinforced or reinforced. The operation should be performed in a controlled environment indoors near to the installation site.

The wet-out table has a powered, wide conveyor belt with a set of pinch rollers that the impregnated liner is rolled through. The resin is mixed, and a pre-measured amount injected into the fabric tube which is drawn through the calibrated pinch rollers set to a gap that achieves the required design wall thickness. The liner must be evenly saturated with the correct volume of resin without dry patches or air pockets. This is assisted by performing the impregnation under a vacuum to exclude air and ensure the uniform distribution of resin.

4.2.2.2 UV cured liner impregnation

UV cured liners are usually impregnated with resin at a manufacturer's premises. The wet-out procedure is complicated by the resin being light sensitive and the fabric tube having both an inner and an outer membrane.

4.2.2.3 Ambient cured liner impregnation

Liners that cure in the ambient air temperature are impregnated with resin like the thermal cured resins described above.

4.2.3 Liner handling equipment

A liner that is thermal cured, once wetted out must be stored and transported in a chilled or refrigerated vehicle with temperature controls and thermometers.

A liner that is UV cured, once wetted out, must be put in light proof packaging and strong crates, with appropriate signage, for storage and transportation.

The liner must be stored near to the insertion point, ready for installation, on a vehicle or on the ground.

The liner shall be lifted off its storage position by crane and pulled towards the insertion point. The use of raised rollers may be necessary to support the liner. In addition, for pulled in liners suitable rollers must be located where the liner will turn to enter the host pipe.

4.2.4 Insertion equipment

4.2.4.1 Water pressure inversion equipment

The inversion equipment will comprise a scaffold tower supporting the inversion guide tube and a regulated water supply to fill the liner. Rollers and a crane shall be positioned near the stored liner to assist in conveying the liner to the scaffold tower.

The scaffold tower shall be designed to support the liner and equipment at the height calculated to provide sufficient water head to insert the liner through the host pipe and apply sufficient pressure to ensure a tight fit and overcome any water table present.

The inversion guide tube shall have a suitable clamping collar at the top to secure the open end of the liner. The guide tube shall lead the liner into the manhole chamber and may include a bend to assist the liner turning to enter the host pipe.

At the insertion point a water supply shall be established to supply the water tower and the heating equipment. The water supply to the tower shall be regulated to control the rate of inversion.

Equipment shall be provided to slow the rate of inversion should the need arise to avoid the liner running away out of control. This might be mechanical brakes on the main roller or a braking system with capstan or anchor.

The dead end of the liner shall be clamped closed to be watertight, and have a rope strongly fixed to it. The rope shall be strong enough to withstand the forces on the inverting liner and heat resistant as it will remain in the inverted liner until the liner is fully cured. The hot water delivery hose from the water heater shall be attached to the liner dead end to ensure the hot curing water circulates from the very end of the liner back to the tower.

At the end manhole it may be necessary to have bracing to support the end of the liner which will be under pressure.

4.2.4.2 Air pressure inversion equipment

Another method to invert the liner is to use air pressure with an air inversion launcher also known as a blower, drum or air gun. This equipment is used for smaller and shorter liners. The impregnated liner is coiled inside a steel drum such that when the drum is pressurised with air the liner inverts out of a nozzle. The nozzle is aimed at the entrance to the pipe being lined. The air pressure in the drum is regulated to control the speed with which the liner inverts into the pipe.

4.2.4.3 Pulling in equipment

A winch with sufficient power and appropriate brakes and struts shall be positioned over the pulling end of the pipeline. The winch shall be provided with sufficient fuel. The winch shall have a load gauge to measure the pulling force. The cable shall be of adequate strength for the operation. The cable shall be attached securely to the liner end with a swivel to avoid the cable twisting the liner. Cable rollers with braces, suitable for guiding the cable from the winch down and into the host pipe shall be provided. The system must ensure that the liner is not damaged during the installation. Rollers may be required to convey the liner down into the host pipe.

4.2.5 Pressurisation equipment

4.2.5.1 Water tower

The scaffold tower is used to monitor the water level that indicates the pressure on the curing liner.

4.2.5.2 Air pressurisation equipment

A compressor shall be parked near the end point of the operation. The compressor shall be provided with sufficient fuel. The compressor shall be able to provide the necessary pressure to keep the liner inflated at the required pressure and pressure gauges shall be visible. The pressure hose and connectors shall be of suitable rating.

For UV light curing, the uncured liner shall have sealing end packers fitted at each end. They shall make an airtight seal with the liner and have air locks allowing pulling and power cables of the UV light train to operate. The packers shall be secured to the liner such that they will not be forced off once the liner is pressurised. The packers shall be located outside the host pipe ends to avoid damaging the liner in the host pipe end.

For steam cured liners manifolds shall be connected to the ends of the liner. The manifolds shall be connected to inlet and outlet air/steam hoses. The manifolds shall be mounted with temperature and pressure sensors. The inlet air/steam hose shall be connected to an air compressor and steam generator of sufficient capacities and shall have monitoring and control equipment.

4.2.6 Curing equipment

4.2.6.1 Hot water curing equipment

The water heating unit (boiler) is a large item of plant that is usually mounted on a vehicle. It heats the water and circulates it through the liner. The plant must have sufficient capacity and heating capability to cure the liner. It shall have sufficient fuel for the duration of the curing process. There shall be gauges displaying the pressure, height of water column, the rate of circulation and the temperature out of boiler, of the return water as well as at the two ends of the host pipe.

The hot water delivery hose(s) from the water heater is attached to the liner dead end to ensure the hot curing water circulates from the end of the liner. These hoses are usually lay flat hoses. A hot water return hose shall be inserted into the water column to take the returning hot water back to the water heater completing the hot water circulation. The hoses shall be suitably strong and of sufficient diameter and length.

The curing process shall be planned in terms of temperature cycles, timing, pressures and flows. The pressure, height of water column, the rate of circulation and the water temperature out of the boiler, of the return water as well as along the liner and at least at the two ends of the host pipe (using sensors) must be measured and recorded in a log and presented to the Owner on completion of each curing operation.

4.2.6.2 UV light curing equipment

The curing control unit is usually self-contained with a winch, power supply and operating controls. The cable from the winch travels over braced rollers to enter the liner through a sealing end packer and is attached to the light train.

The lights may be ultraviolet (UV) lamps or LEDs.

The light train comprises lights mounted on a carriage that can be adjusted for length and diameter. The light train shall be adjusted so that the lights are centred in the liner diameter to ensure equal light intensity around the liner perimeter. The emission spectrum of the lights must match the absorption wavelength range of the photo-initiator in the resin. The lights shall be cleaned and checked prior to use. Each light should have a logbook of use and must be replaced once its usable life has been exceeded. The power, number of lights and travel speed are calculated to provided sufficient light to cure the liner. The controls must indicate the travel rate of the UV light train and power supplied.

The light train usually has a CCTV camera to allow the inspection of the inflated liner before curing to see that it is correctly positioned. The light train may have infrared sensors and thermocouples to record the exothermic temperatures on the interior surface of the liner at regular intervals during the curing process to gauge the cure progress.

A temperature sensor system is required along the liner and at least at the two ends of the liner. The sensors must have calibration certificates.

The curing process shall be planned in terms of liner air pressure, number of lights, power, timing, travel rate, distance and liner inner surface temperature.

The liner air pressure, which lights are operating, power, intensity limits, timing, travel rate, distance and liner inner surface temperature must be measured and recorded in a log and presented to the Owner on completion of each curing operation.

4.2.6.3 Steam curing equipment

The steam generator (boiler) shall have sufficient capacity and equipment to monitor and control the pressures, temperatures and flows.

4.2.7 Other equipment

4.2.7.1 CCTV camera equipment

The CCTV camera shall be purpose built for inspecting pipelines, mounted on a tractor with lights, display and recording equipment.

4.2.7.2 Robotic cutter

The robotic cutter shall be purpose built for operating in pipelines, mounted on a tractor with lights, cutters, display and recording equipment. The equipment will be used to open holes in the liner where the lateral pipes need reconnecting. The robotic cutter might be used in conjunction with a separate CCTV camera.

4.3 Construction

The insertion and curing of the liner between two or more manholes can typically be done within a day or two. However, the proper planning and preparation needed is critical to the successful installation of the liner.

4.3.1 Preliminary planning

4.3.1.1 Planning the lining

Liners are typically installed between manholes. It can be advantageous to line through an intermediate manhole as this reduces the number of setups and provides a convenient place to arrange for liner test samples. Liners are typically inverted downstream to allow the free drainage of any water away from the liner inversion face. A plan showing the details and sequence of individual linings is essential to planning and coordinating the entire works.

4.3.1.2 Wayleaves

All wayleaves and permissions necessary for occupation and excavation must be planned and applications made.

4.3.1.3 Safety

All safety plans must be reviewed. This must include a plan for working in confined spaces.

With reference to styrene, work areas must be well ventilated and good housekeeping practiced on the project and installation site. Styrene odours should be minimised to avoid creating a nuisance to residents. House traps must be full of water. The measures to be applied shall be recorded in a styrene safety plan.

4.3.1.4 Notices to residents

Any residents affected by the work must be notified in writing and any queries answered and problems resolved.

4.3.1.5 Planning for traffic accommodation

The accommodation of traffic shall be planned, including all signage and notices. All necessary arrangements with the relevant authorities for approvals, road closures, traffic deviations and traffic control must be confirmed.

4.3.1.6 Pipe inspection and re-connection plan

A detailed CCTV inspection of all defects and connections into the pipeline to be lined shall be done and a recording and report on this inspection shall be made available to the CIPP Designer.

The internal diameter of the host pipe must be measured to verify previous measurements, records or assumptions, before the liner is ordered.

The exact length of the host pipe should be measured and recorded. That length, together with other installation requirements is then used to determine the length of liner to order.

All connections with distances, sizes and positions shall be recorded for exposing after lining. This information must be correlated with the known connections from properties.

4.3.1.7 Review of inspection and declared design parameters

The inspection shall be reviewed in the light of previous inspections and the CIPP Designer shall confirm all the declared design parameters. Any changes shall be discussed with the CIPP Contractor. This may require a redesign of the liner wall thickness.

Any new risks or concerns revealed must be discussed, and amelioration measures implemented if possible. Any new risk must be attributed to one of the parties.

4.3.1.8 Planning point repairs

Any point repairs must be planned in terms of excavations, shoring, dewatering, traffic, managing flows and repairs, and included in the works programme. It may be advantageous to repair short sections of the host pipe with a short CIPP repair liner using an inflatable packer.

4.3.1.9 Planning for pipeline cleaning

The current state of the host pipe must be evaluated to plan its cleaning and inspection.

4.3.1.10 Planning for overpumping

The overpumping of the sewage or stormwater shall be planned so that it is discharged past the section of pipeline being lined. The planning shall include the checking of pipeline capacities, actual flow volumes (using a 24 hour dip survey) including an allowance for peak, wet weather or surcharged flows. The plan shall include flow extraction, location of pumps and power plants, hoses, pipes, pipe routes and discharge points.

There shall be a contingency plan for failure of the overpumping system that includes having standby pumps and power supplies.

The overpumping system shall remain in place until the works (lining, testing, re-connections) have been accepted by the Owner.

4.3.1.11 Planning for taking liner samples for testing

Samples shall be prepared and tested for each and every section of lining installed and cured.

The location(s) for taking test samples shall be planned. The liner must be constrained to go through a special pipe section that has the same internal diameter as the host pipe, where the samples can be taken and that part of the liner must also be properly and fully cured.

For small to medium size pipes, a sample should be cut from the liner at an intermediate manhole or at the termination pipe. The liner shall have been inverted through a pipe section of the same diameter, which has been held in place by a suitable heat sink, such as sandbags.

For larger pipe sizes and where it is not possible to insert the liner through a special pipe section, the sample shall be prepared before curing by fabricating the sample from material taken from the tube and the resin/catalyst system used. The sample is then put in a clamped mould and inserted into the inversion guide tube for curing in hot water with the liner, or is positioned in the liner for UV curing liners.

The samples shall be large enough to provide 5 specimens (3 specimens minimum) for flexural and tensile testing.

The CIPP Contractor and the Owner shall agree on a nominated laboratory to test the samples, unless a specific laboratory has been specified in the specification data. The chain of custody of the test samples shall be planned and recorded.

4.3.1.12 Planning for resin impregnation (wetting out)

The resin impregnation of UV cured liners is usually performed in the manufacturer's premises under factory controlled conditions.

For thermal cured liners impregnated by the CIPP Contractor, the location, equipment and materials for wetting out shall be planned to include the roller gaps, mix proportions, and volumes.

The subsequent storage and transportation must be planned to avoid damage or premature curing of the liner.

4.3.1.13 Planning for the insertion of the liner

The insertion of the liner, whether by pulling in or inversion must be planned, with details of the scaffold tower or winching system and pressurisation equipment. The maximum allowable pulling load for the liner shall be determined. The required water column or air pressure for inversion shall be calculated. If specified, the installation of hydrophilic seals must be included.

4.3.1.14 Planning the pressurisation of the liner

The curing pressure is the pressure required to ensure the liner fits tightly to the inside of the host pipe and overcome any water table pressure and any potential pressures from wastewater in lateral connections.

For hot water cured liners, the required water column for inversion and for curing shall be calculated.

For liners installed by air inversion, the required air pressures must be calculated.

For liners cured by steam, the air/steam pressure shall be calculated.

For UV curing the required air pressure shall be calculated.

In calculating the required pressures, the need to create dimples to find lateral connections should also be considered.

The maximum allowable internal and external pressures that the liner can withstand shall also be noted, so that they are not exceeded.

4.3.1.15 Planning for curing of the liner

For hot water curing of the liner the temperatures, times, pumping rates and sensor locations shall be planned.

For steam curing, the generation rates, exhaust rates, temperatures, pressures, times and sensor locations shall be planned. The planning shall include the safe release of exhaust steam into the atmosphere.

The curing cycle for hot water and steam curing, is usually a two-stage heating process followed by a cooling down stage. The times and temperatures of the curing stages are highly variable and depend on the liner, length, diameter, thickness, resin type, catalyst formulation, water heater size, flow rate, host pipe material ground conditions, environmental and site conditions.

For UV curing the lights, power, sensors travel rate and times shall be planned. The liner manufacturer’s light intensity limits that ensure a proper and safe curing of the resin, shall be stated.

4.3.1.16 Planning records

The plans for lining, wayleaves, safety, residents’ notifications, traffic accommodation, re-connections, declared values, point repairs, pipeline cleaning, overpumping, testing, wetting out, insertion, pressurisation and curing are to demonstrate due diligence and identify any problem areas. The plans shall be prepared, submitted to the Owner for comment and placed on the record, prior to their implementation.

4.3.2 Preparation

4.3.2.1 Works programme

A complete detailed works programme covering all the lining operations including cleaning, CCTV inspections, overpumping, point repairs, liner impregnation, insertion, curing, testing, re-connections and final CCTV inspection showing key dates and critical path must be approved by the Owner.

4.3.2.2 Wayleaves

Copies of all the required wayleaves and permissions must be kept on site. They must be adhered to and maintained.

4.3.2.3 Safety

All the necessary safety equipment, safety measures and personnel must be in place and checked against the safety plans. Confined access measures must be implemented. The styrene safety plan must be implemented.

4.3.2.4 Traffic

All traffic accommodation measures must be in place.

4.3.2.5 Detailed impregnation and curing schedule

The mixing, impregnation and curing schedule shall be strictly in accordance with the liner/resin manufacturers specifications/instructions.

A detailed schedule for impregnating and curing the liner shall be provided. The impregnation of the liner with resin must include the resin mix, additives and mixing instructions, roller gap, transportation and storage details.

The curing schedule for hot water curing must include water column height, sensor positions, pressures, circulation rate, heating and cooling cycle temperatures and times.

For steam curing, the schedule shall include pressures, sensor positions, steam generation and exhaust rates, heating and cooling cycle temperatures and times.

For UV curing the air pressure, number of lights, power, intensity limits, travel rate, temperatures and sensor positions.

There shall be a contingency plan should any of the key equipment fail.

4.3.2.6 Pipeline access points

The access points to the pipeline must be opened up. Usually this will require the removal of the top of the manhole structure included cover and frame, access shaft and cover slab. Safe and easy access and egress for personnel, must be available at all times.

4.3.2.7 Overpumping

The overpumping system must be in place and ready.

4.3.2.8 Property connections

All connections from properties shall be plugged with the knowledge of the property Owners. It may be necessary to have a vacuum tanker on standby to relieve any potential overflows.

4.3.3 Host pipe preparation

4.3.3.1 Pipe cleaning

If necessary, the pipeline must be cleaned, and all silt, debris and roots removed and disposed of in accordance with the environmental management plan and at a waste disposal site licenced to receive such waste that may be categorised as hazardous. All this waste material must be collected at the downstream manhole using dams/screens and not allowed to pass further downstream. Care shall be exercised with jetting equipment to avoid damage if the host pipeline is fragile. Any obstructions such as protruding connections or stubborn deposits in the pipeline must be removed with specialised equipment (scrapers, robotic cutters). Any deposits or obstructions that could not be removed during the cleaning process may need to be removed using a point repair. The bore of the host pipeline must be sufficiently clean to allow the liner to fit into it tightly.

The cleaned pipeline must be inspected with CCTV to confirm that it is clean.

4.3.3.2 Point repairs

Point repairs shall be implemented as planned. This work is subject to other SANS standard specifications relating to sewer or stormwater construction.

4.3.3.3 Overpumping

Pipe cleaning and point repairs may require overpumping or flow deviations/stoppage to be implemented.

4.3.3.4 State of host pipe to be lined

A CCTV inspection of the host pipeline shall be made after cleaning and after point repairs have been completed. This inspection recording shall be kept as a record of the state of the host pipeline condition prior to lining and be agreed and accepted by the CIPP Contractor and Owner as such. The recording may be used to determine if any irregularities in the host pipe caused any irregularities in the cured liner.

4.3.4 Liner preparation

4.3.4.1 Timing

The timing of the impregnation of the liner with resin is dependent on the programming of other operations and where the impregnation will take place.

In the case of wetting the liner out on site, it is usually inserted into the pipeline soon afterwards.

If the liner is impregnated in the factory of a European manufacturer and transported by sea or air, all site operations are dependent on the arrival of the liner.

4.3.4.2 Resin volume

The volume of resin used shall be adjusted for the resin absorption properties of the particular liner and resin system, change in resin volume due to the polymerization and thermal expansion and contraction. If there will not be a membrane between the resin and the host pipe wall, an allowance may be necessary for the migration of resin into cracks and joints in the host pipe. The CIPP Contractor shall calculate the required roller gap taking the above into consideration as well as the longitudinal folds in the liner. The impregnated fabric tube shall have a uniform thickness so that when compressed at installation pressures, the cured wall thickness excluding membranes will not be less than the declared design wall thickness.

4.3.4.3 Thermal cured liner impregnation

The wetting out of thermal cured liners is commonly performed by the CIPP Contractor under controlled conditions.

The resin must be mixed including any additives, according to the resin manufacturer’s product instructions.

The fabric tube is mounted on the wetting out table. A measured amount of catalysed resin is injected into the fabric tube which is drawn through the calibrated pinch rollers set to the required gap. The suction heads are positioned over vacuum holes made in the liner and advanced as the liner progresses. The liner must be evenly saturated with the correct volume of resin without dry patches or air pockets. The vacuum holes must be properly patched and sealed as part of the process. The impregnated liner is folded accordion style into its storage/transportation container.

4.3.4.4 UV cured liner impregnation

UV cured liners are usually impregnated with resin at a manufacturer’s premises or by the Contractor who has constructed suitable facilities on site. The wet-out procedure is complicated by the resin being light sensitive and the fabric tube having both an inner and an outer membrane. Manufacturers might be reluctant to divulge any production details of the liner's assembly and impregnation. Again, the liner must be evenly saturated with the correct volume of resin without dry patches or air pockets.

4.3.4.5 Ambient curing liner impregnation

Liners that cure in the ambient air temperature are impregnated with resin like the thermal cured liners described above. However, once the catalyst is added to the resin the curing commences and the liner must be impregnated and installed into position promptly. Ambient curing liners may be chilled or retarders used to slow the curing process.

A sample of resin should be taken from the excess resin mixed and retained to monitor the curing of the resin/liner.

4.3.4.6 Certified records

Once impregnated, the CIPP Contractor or the CIPP manufacturer shall provide a certificate for the liner with project name, installation location, impregnation date, resin type, volume, wall thickness, mixing ratio, additives, temperature, fabric tube type, membranes, unreinforced fabric, reinforced fabric, length, diameter, manufacturer and manufacture date. It shall include any specific curing requirements. The liner shall be labelled with references to the certificate. The certificate shall be kept for the Owners record purposes.

4.3.4.7 Storage and transportation

The impregnated liner must be stored and transported with strict adherence to the manufacturer's product instructions.

In general, a liner that is to be thermal cured must be stored and transported in a chilled or refrigerated vehicle with temperature controls and loggers.

A liner that is to be UV cured must be put in light proof packaging and strong crates, with appropriate signage. UV cured liners also have temperature limitations.

4.3.5 Liner insertion

4.3.5.1 Insertion by inversion

Figure 1 illustrates the typical layout of plant and equipment using the water tower inversion method.

If required in the specification data, a preliner shall be installed by winching it into the pipeline in accordance with the requirements of the following clause. The preliner shall be secured to the inversion guide tube to ensure the liner is inverted inside the preliner.

The liner is transported to be placed as near as possible to the insertion point. Rollers and usually a crane are required to convey the liner onto the scaffold tower. Care shall be taken to avoid over-stressing the fabric/liner at all times.

The scaffold tower must be erected over the insertion point and the inversion guide tube set in position for the required water height requirements for insertion and curing. The insertion guide tube must be positioned to direct the liner into the mouth of the host pipeline. At the end manhole the end brace must be installed in place. Any equipment or constraints for taking test samples of the liner must also be in place. Any temperature monitoring equipment required inside the host pipe must be installed.

The dead end of the liner must be clamped closed to be watertight and a rope securely fixed to it. The hot water delivery hose must be attached to the liner dead end. The rope must be connected to the braking system. The open end of the liner must be securely attached to the guide tube with the clamping collar.

To commence the inversion, the liner is lifted up and pulled towards the insertion point over the rollers. The outside of the liner end is secured onto the inversion ring to form a pocket on the inside of the guide tube. Then the liner is tucked by hand down into the guide tube carefully to avoid any damage. When sufficient liner is in, the pocket formed is filled with water. This will assist the insertion until the liner continues entering the guide without assistance by hand. Thereafter the rate of inversion is controlled by the height of the water column and any necessary braking of the rope.

Lubricants may be used to assist the liner overcome friction.

Once the liner has inverted into the mouth of the host pipeline, the rate of progress must be carefully controlled to be slow and steady. When the liner is halfway in, the dead end of the liner with attachments must be assisted by hand to safely enter the guide tube. The insertion is completed when the liner is fully extended through to the terminal manhole and fully pressurised to the required water head.

Care shall be exercised to ensure that the liner inverts through any pipeline section that is installed for the purpose of taking liner test samples.

The inversion of liners by air pressure follows a similar procedure.

4.3.5.2 Insertion by pulling in

Figure 2 illustrates the typical layout of plant and equipment using the pull in method of insertion. This method is used for UV and ambient curing liners.

The liner is transported to be placed as near as possible to the insertion point. Braced rollers are positioned to convey the liner down and into the host pipeline. Care shall be taken to avoid over-stressing the fabric/liner at all times.

The winch is positioned at the terminal manhole with rollers positioned to guide the cable into the host pipeline. The rollers shall be adequately braced to bear the pulling forces on the cable.

Any equipment or constraints for taking test samples of the liner must be in place. Any temperature monitoring equipment required inside the host pipe must be installed.

The cable is threaded through the host pipeline and the sliding foil fixed to its end with a swivel. On commencing the winching, the foil must be carefully guided down into the host pipeline to avoid damage to the foil. The rate of insertion must be carefully controlled to be slow and steady, and the pulling load monitored to ensure it is below the maximum allowable.

Once the sliding foil is in place the procedure is repeated to install the liner in the host pipeline taking particular care not to damage it.

Hydrant water can be carefully allowed to flow through the host pipeline to allow the tube to slide more easily.

Care shall be exercised to ensure that the liner is pulled and cured through any pipeline section that is installed for the purpose of taking liner test samples.

After the liner is pulled in, the longitudinal elongation of the liner shall be less than 5%.

4.3.5.3 Calibration hose

If a calibration hose is required in the specification data, it shall be inserted, pressurised and incorporated into the above operations as detailed in the specification data.

4.3.5.4 Hydrophilic seals

If hydrophilic seals are required in the specification data, they shall be installed and secured in position as detailed in the specification data, prior to inserting the liner.

4.3.6 Liner pressurisation

4.3.6.1 Thermal curing

The pressure during the curing of the liner with hot water is determined by the height of the water column at the scaffold tower. This level must be continuously monitored during the curing and adjusted as necessary to be between the required pressure and the maximum allowable pressure.

Similarly for steam curing, the air/steam pressure must be continuously monitored and adjusted as necessary to be between the required pressure and the maximum allowable pressure.

4.3.6.2 UV curing

Sealing end packers shall be secured into the ends of the liner that protrudes beyond the ends of the host pipe. The air hose from the compressor is connected onto the packer in the end manhole. The compressor shall inflate and hold the required air pressure in the liner. The air pressure shall be continuously monitored and adjusted as necessary to be between the required pressure and the maximum allowable pressure.

4.3.6.3 Ambient curing

These liners are pulled into the host pipe and then inflated using either a reusable calibration hose or an integral calibration hose which becomes a permanent part of the liner. For liners that are inverted with water, the column of water must be maintained in the tower until the cure is completed.

4.3.7 Liner curing

4.3.7.1 Hot water curing

Figure 1 illustrates the typical layout of plant and equipment.

The inflow and return hoses shall be connected up to the water heater (boiler). The boiler pump must circulate the heated water at the required rate through the hoses and the liner. The pressure, height of the water column, the rate of circulation and the water temperature out of the boiler, of the return water as well as along the liner and at least at the two ends of the host pipeline (using sensors) must be measured, monitored and adjusted in accordance with the curing plan for the duration of the curing cycle.

The curing cycle must be continuous including the necessary cooling down stage, which usually entails stopping heating the water but continuing circulation of the water until the water cools to the required temperature. To achieve this, it may be necessary to replace some of the heated water with cold water. The readings shall be recorded in a log and presented to the Owner on completion of the curing operation.

As a contingency measure to ensure adequate circulation and curing of the end of the liner, small holes may be punched into the end of the liner to allow heated water to flow through right to the end of the liner. Adjustments must be made to the heating, pumping rate and water level to take this into account.

4.3.7.2 Steam curing

The inflow and outlet hoses shall be connected up to the steam generator. The generator must distribute the steam at the required rate through the hoses and the liner. The pressures, temperatures, rate of circulation must be measured, monitored and adjusted in accordance with the curing plan for the duration of the curing cycle.

The safe discharge of exhaust steam shall be monitored.

The curing cycle must be continuous including the necessary cooling down stage, which usually entails gradually replacing the steam with air to cool the liner down to the required temperature. To achieve this, it may be necessary to replace some of the heated water with cold water. The readings shall be recorded in a log and presented to the Owner on completion of the curing operation.

4.3.7.3 Ultraviolet light curing

Figure 2 illustrates the typical layout of plant and equipment.

The UV light train shall be connected up, checked and tested on the surface before being introduced into the liner. The compressor shall maintain the required pressure in the liner. The light train cables and the winch cables shall pass through the seals in the end packers.

The light train with CCTV camera attached is winched through the liner to confirm that the liner is correctly in position. The light train is then lit and winched through the liner at the required travel rate for curing. The lights shall be set at the required power. The liner air pressure, which lights are operating, power, intensity limits, timing, travel rate, distance and liner inner surface temperature must be measured, monitored and adjusted in accordance with the curing plan for the duration of the curing cycle. The readings shall be recorded in a log and presented to the Owner on completion of each curing operation.

4.3.7.4 Ambient curing

Ambient curing liners commence curing once the catalyst is added to the resin and harden relatively quickly. In the event of an early cure before installation these liners are to be removed and not re-used.

A sample of resin retained from the excess resin mixed is used to monitor the curing of the resin/liner.

4.3.8 Completion of installation

4.3.8.1 Re-establishment of flow

Care shall be exercised emptying water from the liner, to avoid low pressures or a vacuum that could damage the liner.

4.3.8.2 Removal of plant and equipment

On the successful completion of the liner installation and curing, the plant and equipment used for the insertion and curing of the liner may be removed. The overpumping system may only be removed with permission of the Owner or once the liner has been accepted by the Owner.

4.3.8.3 Treatment of liner end

The parts of the cured liner outside of the host pipe shall be removed and the liner ends trimmed neatly back to the end of the host pipe. The seating of any hydrophilic seals required by the specification data shall be checked. If the liner does not fit tightly against the host pipe at the pipeline ends, the annulus between the liner and the host pipe ends shall be sealed with an appropriate cement or epoxy grout to a depth of at least ten times the width of the annulus to provide a watertight seal.

4.3.8.4 Re-establishing connections

On completion of the curing of the liner and after the liner has cooled and been allowed to relax such that relative movement between the liner and the host pipe has stopped, all existing property connections shall be re-established. The resulting dimples in the liner must be used together with the connection record to ensure all connections are remade.

Wherever possible the connections shall be remade without excavation by means of a robotic cutter and a CCTV camera (or by hand if man entry is permissible). The cutting tool shall leave a smooth bevelled edge free and shall be flush with the inside surface of the connecting pipe. The bottom of the opening in the liner and the invert of the connection pipe shall match to allow the connection pipe invert to drain into the main pipe. The opening shall be such that the connection shall have at least 90% of its original capacity. The opening shall be free of any sharp edges or protrusions, which could cause paper, rags, or debris to snag or accumulate on.

If required in the specification data, the lateral connections shall be rehabilitated in accordance with the supplementary specifications. This may include lining the connection pipe, installing a junction liner (Top Hat), chemical grouting, resin injection or rehabilitation by point repair.

A CCTV recording of all the re-established connections shall be provided. Once the Owner has accepted the liner and re-connections, and the pipeline has been re-commissioned, plugs in the property connections shall be removed and the property owners advised accordingly.

4.3.8.5 Reinstatement of manholes

The manholes used for access for the installation shall be re-established including walls, cover slabs, access steps, cover and frames and surface reinstatement. The reconstruction shall be in accordance with other SANS standard specifications and any additional improvements detailed in the specification data.

5 Compliance with the requirements

5.1 Tolerances

Unless stated otherwise in the specification data, the tolerances to be checked are stated in 5.2.6.

5.2 Testing

5.2.1 General

The specification data shall prescribe any tests in addition to those specified below.

5.2.2 CCTV Inspection

A CCTV inspection shall be performed of the cured liner and recorded with a written report including all connections remade and all defects found. Photographs of the ends of the host pipe and liner shall be included.

The video recording of the CCTV inspection of the lined pipeline shall be assessed to check that the liner is continuous over its entire length and has no leaks, deformations or other defects that will affect the performance or structural integrity of the pipeline. Any such defects shall be recorded.

5.2.3 Acceptable liner finish

The liner shall be continuous over the whole length of the host pipeline, it shall be fully cured throughout its length and be a tight fit to the shape of the existing pipeline. There shall be no deformations (except in sympathy with defects in the existing pipeline), twists, wrinkles, bubbles, cracks, foreign inclusions, dry spots, lifts, pinholes or delaminations. The liner shall be free of leaks and defects that will affect the integrity or strength of the lining.

Wrinkles should not be of a height greater than 2.5% of the liner diameter but may be acceptable if the liner rounds a curve or bend.

Horizontal fins are usually acceptable, they are a consequence of the inner face of the liner not having enough perimeter to expand into the host pipeline due to the liner being too large or there is a reduction in the inner diameter of the host pipeline. They should have no significant effect on the function of the pipe and can usually remain.

If the liner has run over debris on the invert of the host pipe, it shall be removed and repaired if it significantly affects the hydraulics of the flow through the pipeline.

All unacceptable defects shall have their location, description and proposed repair recorded.

The Owner may accept defects that are not significantly detrimental to the long term structural and/or hydraulic performance of the liner. It might be desirable to keep the liners finished integrity intact, instead of making repairs to the liner which may introduce other imperfections.

Should there be defects that indicate deficiencies in the liner in terms of liner construction or curing, the Owner may order liner samples, additional to those planned, to be taken for testing.

5.2.4 Liner repairs

The defects in the liner shall be repaired and the repairs re-inspected and accepted before the pipeline is re-commissioned.

5.2.5 Structural testing

5.2.5.1 CIPP Test Samples

When the liner has fully cured, test samples shall be taken from the liner as planned. The samples shall be large enough to provide 5 specimens (test coupons) (3 specimens minimum). The specimens should be cut from the sample using machining, water jet cutting or laser cutting. The sample details shall be recorded, and the samples labelled and taken to the nominated testing laboratory. There shall be a complete record of the chain of custody.

Specimens shall be cut with their longitudinal axis orientated perpendicular to the longitudinal axis of the liner. The aim is to measure the flexural properties in the hoop direction of the pipe.

For reinforced liners the specimens shall be at least 50 mm wide (measured in the axial direction (along the length of the liner)), to include representative amounts of reinforcing fibres.

5.2.5.2 Laboratory testing

The short term flexural (bending) properties shall be determined. The initial tangent flexural modulus of elasticity and the flexural strength shall be measured in accordance with ASTM D790.

For flexural and tensile tests any specimens with plastic membranes, that have not been included in the structural design, must have these carefully ground off prior to testing.

The CIPP liner diameter and wall thickness shall be determined in accordance with ASTM D5813 Section 8.1.2 and ASTM D3567. Note that the wall thickness of the liner shall exclude any plastic coatings or membranes.

Where ordered by the Owner, samples shall be submitted for long term testing in accordance with ASTM 2990.

Where specified in the specification data, samples shall be taken and submitted for chemical testing.

5.2.6 Acceptance

5.2.6.1 Acceptable structural properties

The minimum allowable outside diameter of the liner shall be 98% of the declared inside diameter of the host pipe or special pipe section for taking samples. This is to allow for diametric shrinkage of the liner during curing.

The average thickness shall be calculated from all the measured values (excluding the thickness of any membranes) and shall meet or exceed the declared design wall thickness. The minimum wall thickness at any point shall not be less than 87.5% of the declared design wall thickness.

The Short Term Flexural Modulus of Elasticity and the Short Term Flexural Strength of the test specimens shall not be less than the declared values.

5.2.6.2 Testing records

The CIPP Contractor shall submit a compilation of all test results for each CIPP liner installation.

All leaks, deformations or defects shall be rectified, and a further CCTV inspection undertaken and re-submitted for assessment.

5.2.6.3 Review of design

On request, the CIPP Designer may review the design of the liner, where any test results fail. This may be the consequence of one property being less, but another higher than requirements (for example the flexural modulus is less than the declared value, but the thickness is higher than the declared value). Such design review shall include a review of all design parameters. The acceptance of any such reviewed designs that meet the design requirements shall be at the discretion of the Owner.

5.2.6.4 Approval of installed pipeline

The section of pipeline that has been installed may only be accepted by the Owner, once it has passed all the required tests and the CCTV inspection, confirming that any defects have been rectified, has been accepted.

Annex A
(normative)

Preparation of specification data associated with this part of SASTT-TS-TT4 for inclusion in the scope of work

This specification data forms an essential element of this part of SASTT-TS-TT4; without such data, the requirements are incomplete.

The format for the specification data has been developed to be compatible with the requirements of table D.1 of SANS 10403:2003. The specification data should be incorporated in the scope of work as illustrated in table A.1.

Table A.1 — Incorporating this part of SASTT-TS-TT4 in the scope of work

<table>
<tr><td>1</td><td>2</td><td>3</td></tr>
<tr><th>Topic</th><th>Aspect</th><th>Text</th></tr>
<tr><td colspan="3">CONSTRUCTION</td></tr>
<tr><td rowspan="3">Works specifications</td><td>Applicable part(s) of SASTT-TS</td><td>The following parts of SASTT-TS and associated specification data are applicable:
1) SASTT-TS …..
2) SASTT-TS …….
The associated specification data are as follows:
<table><tr><td rowspan="3">Specification data pertaining to SASTT-TS - ……</td><td>Essential Data:
The requirements for ……. are ……….
The requirements for ……. are ……….</td></tr><tr><td>Variations:
1)……
2)……….</td></tr><tr><td>Additional clauses:
1)…….</td></tr></table></td></tr>
<tr><td>Applicable national and international standards</td><td></td></tr>
<tr><td>Particular/generic specifications</td><td></td></tr>
</table>

Develop the specification data based on the contents of table A.2.

Table A.2 — Specification data associated with this part of SASTT-TS-TT4

1	2	
Specification data associated with this part of SASTT-TS-TT4	**Guidance notes.**	
	Clause number	**Consideration**
Essential Data		
The fabric tube shall ……..	4.1.1	Particular requirements of the fabric tube required for the project.
The resins shall ………….	4.1.5	Particular requirements of the resins required for the project.
A preliner shall be installed prior to the liner insertion.	4.1.2/4.3.5.1	Specify if a preliner is required for unreinforced liners, reinforced liners or both.
The sliding foil for pulled in liners shall be …	4.1.3	Specify any specific requirements if any.
A calibration hose of ….............. shall be supplied and used in the installation of the liner.	4.1.4/4.3.5.3	Specify if a calibration hose is to be used with details.
Hydrophilic seals shall be installed ….	4.1.8/4.3.5.4/4.3.8.3	Specify if hydrophilic seals are required and their specifications.
The liner shall have resistance to the following additional specific corrosion agents …	4.1.9.3	Specify if the liner must withstand corrosion agents in addition to the ones stated in 4.1.10.2
The following chemical resistance tests shall be performed on the liner.	4.1.9.3/5.2.5.2	Specify if the liner must be subject to chemical resistance tests.
Testing of liner samples shall be performed by	4.3.1.11	Specify if a specific laboratory is to perform the tests.
Lateral connections shall be rehabilitated as follows ……………	4.3.8.4	Specify the methods, specifications and payment clauses accordingly.
Manholes used for access shall be reinstated with the following additional requirements.	4.3.8.5	Specify what additional requirements there must be.
Additional tolerances are …....	5.1	Specify any additional tolerances
Additional tests to be performed on the liner are ….	5.2.1	Specify any additional tests.

1	2	
Specification data associated with this part of SASTT-TS-TT4	**Guidance notes.**	
	Clause number	**Consideration**
Additional clauses: 1 ………… 2 …………		*State additional requirements, if any.*
Variations: 1 Replace … with the following: 2 The provisions of … do not apply.		*State variations, as applicable.*

Annex B
(informative)

Notes on the application of *ASTM F1216 Appendix X1 – Design Considerations* to the liner design

B.1 Introduction

It is stated in this standard that the liner wall thickness shall be designed in accordance with American ASTM F1216 Appendix X1 – Design Considerations[1]. In this instance, the word “design” means the determination of a liner wall thickness that will theoretically withstand the various loads and loading conditions exerted on the liner after installation.

This Appendix X1 has been used for the design of many CIPP liners. It is straightforward and once the parameters and properties are determined, the calculations can be performed easily, and it is suitable for spreadsheets. Methods from other countries are either complicated, theoretical or difficult to use. It has been said that Appendix X1 tends to be more conservative, but not overly so. ASTM F1216 Appendix X1 is internationally a well-accepted design method and it is recommended for application in South Africa, where it is applied quite widely.

B.2 Tendering

Initially the project will be at a tender or negotiation stage. At this stage there may be several CIPP Contractors bidding to get the work. There may be several types, manufacturers and strengths of liner available and suitable for the lining. For each bid there will be a different liner, wall thickness and price. In order to evaluate the different tenders, the tender documentation must state the design parameters and the tenderers must tender on a liner giving its wall thickness, structural properties and price. To do this the tenderers must perform the calculations in Appendix X-1. In the evaluation the liners tendered must meet the requirements and then the award can be made on price. This method of tendering is fair but does require the tenderer (or manufacturer) to perform the calculations. It also requires the Owner or CIPP Designer to determine the design parameters as accurately as possible. It is important that the CIPP Designer checks the tenderer’s calculations. The installed liner is tested to check that it meets the structural properties tendered by the CIPP Contractor.

Another method of tendering for CIPP work is for the tender to specify a selection of pipe wall thicknesses to be priced and require that the tendered structural properties of the tendered liners must meet minimum values. The award of the tender is then based on price. In this instance the Owner or CIPP Designer must determine the thickness of liner required for lining a particular pipeline and order the CIPP Contractor to install it. This tender method does not allow liners with higher structural properties to compete with liners that just meet the minimum values.

B.3 Application

Essentially Appendix X1 is divided into two types of pipelines, gravity pipelines and pressure pipelines and two types of pipe condition, partially deteriorated and fully deteriorated.

The scope of this standard covers gravity pipelines only.

For partially deteriorated gravity pipelines there are two equations to be used to calculate the minimum wall thickness. The greater of these shall be adopted.

For fully deteriorated gravity pipelines there are four equations (the two used for the partially deteriorated condition plus two others), to be used to calculate the minimum wall thickness for each. The greatest of these shall be adopted.

Overriding the equations for calculating wall thickness is a statement "NOTE X1.2 - If there is no groundwater above the pipe invert, the CIPP should typically have a maximum SDR of 100, dependent upon design conditions." There is no description of such design conditions, however this statement introduces an absolute minimum liner wall thickness, which prevents very thin liners. Therefore, a 200 mm diameter pipe will not have a liner thinner than 2 mm and a 1000 mm pipe will not have a liner thinner than 10 mm, which makes sense from an empirical point of view.

It is recommended that this maximum SDR of 100 be applied in addition to the formulae. (This means a minimum wall thickness of 1% of the liner diameter.)

B.4 Parameters and properties

In order to calculate the design wall thickness of the liner, several design parameters must be determined, and structural properties of the proposed liner stated. Once done, these design parameters and liner properties can be used to determine the design wall thickness of the liner.

B.4.1 Design parameters

The design parameters must be determined by the CIPP Designer. These must be determined as accurately as possible at tender stage, so that little or no changes need to be made to the design before the liner is installed.

The following notes are a guide and engineering judgement must be applied when determining the design parameters.

B.4.1.1 Gravity Pipe or Pressure Pipe

This standard is intended for the lining of gravity pipelines.

B.4.1.2 Partially or Fully Deteriorated Design Condition

B.4.1.2.1 Design

Appendix X-1 states:

> "X1.1.1 *partially deteriorated pipe* – the original pipe can support the soil and surcharge loads throughout the design life of the rehabilitated pipe. The soil adjacent to the existing pipe must provide adequate side support. The pipe may have longitudinal cracks and up to 10.0% distortion of the diameter. If the distortion of the diameter is greater than 10.0%, alternative design methods are required (see Note 1)."
>
> > (Note 1 on Page 3 is about tensile stress. However, Note X1.3 on Page 6 has no references to it and it discusses designing the liner by tunnel load analysis or "Finite element analysis is an alternative design method for noncircular pipes.")
>
> "X1.1.2 *fully deteriorated pipe* – the original pipe is not structurally sound and cannot support soil and live loads or is expected to reach this condition over the design life of the rehabilitated pipe. This condition is evident when sections of the original pipe are missing, the pipe has lost its original shape, or the pipe has corroded due to the effects of the fluid, atmosphere, soil, or applied loads."

A third condition that may occur is when a pipeline displays no structural deterioration but may need to be lined as the joints are leaking and in the long term the loss of bedding into the pipeline may result in the loss of bedding support and structural collapse of the pipeline. This condition would be considered as a partially deteriorated condition for design purposes.

To decide whether a pipeline is partially or fully deteriorated requires engineering judgement.

The design for the partially deteriorated pipe condition assumes that the existing pipeline can support the soil and surcharge loads and the liner is designed to withstand the hydrostatic forces due to any groundwater. If there is groundwater present it is presumed that the water will infiltrate into the annulus between the liner and the host pipe and exert the full hydrostatic load on the liner. If the liner is not strong enough it will buckle from the hydrostatic pressure. The first equation (X1.1) in Appendix X-1 is the modified Timoshenko equation for buckling. The second equation (X1.2) checks the effect of the pipe ovality.

The design for the fully deteriorated pipe condition assumes the liner must carry all the hydrostatic, soil and live loads. The design comprises four equations, the two (X1.1 and X1.2) equations for the partially deteriorated design plus the (modified AWWA) equation for a buried flexible pipe (X1.3) and equation X1.4.

B.4.1.2.2 Discussion

A pipe that is declared fully deteriorated is consistent with pipe condition grade 5 (WRc SRM[2]) where a pipe is considered to have failed or failure is imminent, has collapsed or collapse is imminent. If a pipe is declared fully deteriorated the liner wall thickness can be calculated, however the risk of collapse whilst working over and inside the pipe must be considered. If a pipe or section of pipe collapses during the installation and curing of the CIPP liner, it will be a catastrophe for all concerned. The Owner should bear all risks associated with lining a fully deteriorated pipe. It could be said that if a pipe is fully deteriorated it is past rehabilitation. (The concept of a fully deteriorated pipe condition is questioned and discussed in the ASCE Emerging Concepts for the Design of pipeline Renewal Systems 2007.)

A pipe that is declared partially deteriorated is consistent with pipe condition grade 4 (WRc SRM[2]) where a pipe is considered in poor condition and collapse is likely in the foreseeable future. Grade 4 pipes are the pipes in any system that should be rehabilitated before they reach Grade 5. Pipes graded 1 to 3 should not need any planned rehabilitation. In the asset management of pipe systems, the trick is to inspect pipes (especially those that are suspect) and find the Grade 4 and Grade 5 pipes timeously. Once a problem manifests itself as a blockage or collapse on the surface it might be too late or risky to rehabilitate.

A pipe that is partially deteriorated might be in equilibrium with its bedding and the surrounding soil when well consolidated. If there is a collapse or breakage that requires excavation to repair it, then the mere exposure of the pipe might lead to the collapse of adjacent pipes and a progressive collapse of the pipeline as it gets more exposed for repair. This is exacerbated if the pipeline is leaking and infiltration of groundwater and exfiltration of wastewater occurs. This might lead to the removal of fines adjacent to the pipeline and the removal of side support.

This is where the controlled exposure of the pipe for inspection is important. Just one inspection pit can reveal many aspects of the pipe that are important to its assessment and the design of the liner. Firstly, it can reveal how good the bedding and side support is. After excavating down to within 0.5 m or 1.0 m of the pipe, probes or a DCP can be used to assess the existing side support and the existence of any cavities. It might be found that the pipe is encased or haunched in concrete, which cannot be determined from an internal inspection of the pipeline. After exposing the pipe, it can be inspected for external corrosion. The pit should be long enough to encompass a joint, so that it can then be also inspected and the configuration determined. A pipe wall sample must be cut from the pipe. The sample should be cut at an angle so that it can be glued/fitted back in place. The size of the sample should be big enough for the inside of the pipeline to be inspected. The pipe wall sample will reveal the thickness of the pipe, the material it is made from, dolomitic aggregate, sacrificial layer, CAC dolomitic layer, reinforcement and any corrosion products. If the sample is corroded, it might be advantageous to take another sample (eg below the flowline) to determine the original wall thickness. The existence of hydrogen sulphide in the pipe atmosphere should be noted and precautions taken. If possible, the external outside diameter should be measured accurately with callipers.

If possible, the internal dimensions of the pipe should also be measured, and any corrosion lips/shoulders noted and their dimensions estimated. An important measurement is from the invert to the outside top of the pipe, this is a dimension unlikely to be affected by corrosion and can be used when looking up the pipe details in pipe catalogues. Probing with a steel rod can give a good indication of unseen erosion or corrosion features. Cracks and fractures must also be explored. Photographs of the exterior and interior of the pipe should be taken. The findings must be evaluated together with the CCTV inspections along the same length of pipeline. The information gleaned from such an inspection may inform the need to perform more inspections elsewhere on the pipeline to check for consistency of the conditions found.

The external inspection of the pipeline is important in determining if a pipe is fully or partially deteriorated. It must be undertaken by the Owner or CIPP Designer. It is also the only opportunity to assess the Modulus of Soil Reaction.

B.4.1.3 Host pipe internal diameter

The internal diameter should be shown on the services drawings but must be checked on site. If the pipe is an imperial size the diameter might not be a round figure (eg 36 inches = 914 mm). Sizes may vary due to mould differences and tolerances. In addition, some concrete sewer pipes included an additional sacrificial layer which reduced the internal diameter.

B.4.1.4 Height of water table above the pipe invert

The existence of a water table must be investigated and if evident then its maximum height above the pipe invert must be decided. If there is no indication of a water table or its height, it might be a reasonably conservative approach to assume the water table is at ground level. If the pipeline is located in an area subject to flooding the water height would be above ground level.

B.4.1.5 Ovality Reduction Factor

Pipe ovality reduces the strength of the liner and if over 10% a different design method must be undertaken. The Ovality Reduction Factor is calculated from the Ovality which is calculated from

Ovality (%) = (Maximum diameter – Minimum diameter) / (Maximum diameter + Minimum Diameter)

If the diameters cannot be measured directly, they can be measured from a photograph of a joint, provided the camera was located near the centre of the pipe.

B.4.1.6 Poisson's Ratio

This is a ratio of the lateral strain to the longitudinal strain of a material loaded longitudinally. Appendix X.1 states that 0.3 is an average value. This value has widespread use.

B.4.1.7 Enhancement factor (K)

The enhancement factor is a factor in the design of a tight fit liner to take into account the casing support provided by the host pipe that reduces the external pressure needed to buckle the liner (compared to an unrestrained liner). The recommended value for this empirical coefficient that was based on statistical analysis of experimental data is 7. It takes into account not only the liner-pipe interaction but also a relatively large annular gap (Aggarwal and Cooper 1984). The WRc (UK) Sewerage Rehabilitation Manual gives a K value of 7 for good conditions (full support) and a value of 4 for worse conditions. If the liner is a very loose fit the enhancement factor could be as low as 1.0.

An Enhancement Factor of 7 has been widely adopted for CIPP applications. Use of other values would need motivation.

B.4.1.8 Factor of safety

This is a factor in design equations that increases the safety and reduces the risk of failure of a product. It also increases the price of the product. It is defined as the ratio between the strength of a material and the maximum allowable stress on it. Factors of safety take into account various unknowns in the design and construction of a product.

The factor of safety is typically 2.

NASSCO[5] specifies 2.0 (1.5 for pipes 36” or larger).

Any reduction in the factor of safety introduces an increased risk that the Owner must understand and accept.

B.4.1.9 Long term creep retention factor for flexural modulus

When the long term flexural modulus is not known the long term creep retention factor (50 year extrapolated) is to be applied to the short term flexural modulus to get a long term flexural modulus.

Flexural modulus is the ratio of flexural stress versus resultant strain (MPa). A high flexural modulus indicates a stiffer material. The short term flexural modulus is usually known for a liner and can be determined by testing.

If a liner is subject to loading and stress in the long term, its flexural modulus will decrease. To determine the long term flexural modulus (50 year) a sample is loaded and tested for a period of 10 000 hours (417 days) and the results extrapolated to 50 years. This is a lengthy procedure and is often undertaken by manufacturers laboratories. However, for convenience a long term creep retention factor is applied to the short term value to get the long term value.

NASSCO[5] specifies a long term creep retention factor of 50% unless there is a long term test result in accordance with ASTM D2990 to substantiate a higher retention factor.

B.4.1.10 Long term creep retention factor for flexural strength

When the long term flexural strength is not known the long term creep retention factor (50 year extrapolated) is to be applied to the short term flexural strength to get a long term flexural strength.

Flexural strength is the strength of a material in bending expressed as the tensile stress of the outermost fibres at the instant of failure (MPa).

Typically, a long term creep retention factor of 50% is used.

The following parameters are applicable in the case of a fully deteriorated design condition:

B.4.1.11 Soil density

The soil density can be measured from a test pit or typical values adopted.

B.4.1.12 Live load

The live load is typically the traffic loads depending on the class of transportation route (roads, railways) over the pipeline.

B.4.1.13 Height of water above top of pipe

The height of water above the invert determined in B.4.1.4 can be used to calculate the same height but above the top of the pipe.

B.4.1.14 Height of soil above top of pipe

This is easily determined from drawings or measurements on site.

B.4.1.15 Water buoyancy factor

This is calculated from the height of water above the top of pipe and the height of soil above the top of the pipe.

B.4.1.16 Coefficient of elastic support

The coefficient of elastic support is calculated from the height of soil above the top of the pipe calculated in B.4.1.14 above.

B.4.1.17 Modulus of soil reaction E^l

The modulus of soil reaction E^l represents the stiffness of the embedment material placed on the sides of a buried flexible pipe. E^l is used to estimate the lateral resistance of the pipeline to deflect due to the vertical loads placed on top of the pipeline. E^l varies with the type of embedment material soil and its degree of compaction.

With an existing pipeline, E^l can be estimated based on assumptions based on the construction practices used when it was buried. A much better method is to perform tests whilst making a test pit adjacent to the pipeline. A geotechnical engineer should investigate and determine the modulus of soil reaction.

If the pipeline is subject to or suspected of leaking (infiltration or exfiltration) there could have been the loss of bedding adjacent to the pipeline resulting in the loss of this side support. Under extreme conditions cavities could form adjacent to the pipeline due to this loss of support.

Determining the modulus of soil reaction E^l is important as in equation X1.3 the design wall thickness is inversely related to it. Hence the smaller E^l becomes, the thicker the liner wall thickness required. If there is no side support ($E^l = 0$) then the wall is infinitely thick. In such situations it will be necessary to decide whether the pipeline is partially or fully deteriorated. If the pipe has no side support and is fully deteriorated the pipeline should not be lined but replaced.

B.4.2 Liner structural design properties

The CIPP Contractor shall state the structural properties of his proposed liner that shall be used for the design of the liner wall thickness. The CIPP Contractor may state structural properties less than those stated by the liner and resin manufacturers, to cover construction risks. The structural properties stated by the manufacturers are often laboratory results, whereas field results might be lower and more applicable for design.

The CIPP Contractor shall submit certificates stating the structural properties of the liner.

The short term structural properties of liners shall not be less than those given in the table below::

Property	Test Method	Unreinforced Liner Minimum Value	Reinforced Liner Minimum Value
Flexural Modulus	D790	1724 MPa	5000 MPa
Flexural Strength	D790	31 MPa	45 MPa

(Note: Designers should not be too prescriptive with the liner type specified. They should focus on the end product required so that any new product innovations that are technically sound and cost effective are not inadvertently be excluded)

B.4.2.1 Short term flexural modulus of elasticity of the liner.

Flexural modulus is the ratio of flexural stress versus resultant strain (MPa). A high flexural modulus indicates a stiffer material. The short term flexural modulus is usually known for a liner either by manufacturers laboratory tests or from field tests.

B.4.2.2 Long term flexural modulus of elasticity of the liner.

This is either a known value or is the short term flexural modulus multiplied by the stated long term creep retention factor.

B.4.2.3 Short term flexural strength of the liner.

Flexural strength is the strength of a material in bending expressed as the tensile stress of the outermost fibres at the instant of failure (MPa). The short term flexural strength is usually known for a liner either by manufacturers laboratory tests or from field tests.

B.4.2.4 Long term flexural strength of the liner.

This is either a known value or is the short term flexural strength multiplied by the stated long term creep retention factor.

B.4.3 Declared Values

The design parameters stated by the CIPP Designer, the structural design properties stated by the CIPP Contractor and the resultant design wall thickness shall be agreed upon as the declared values. The cured liner shall be tested to confirm that it meets these declared structural design properties, liner wall thickness and outside diameter.

On request, the CIPP Designer may review the design of the liner, where any test results fail. This may be the consequence of one property being less than, but another being higher than the requirements (for example if the flexural modulus is less than the declared value, but the thickness is higher than the declared value). Such design review shall include a review of all design parameters. The acceptance of any such reviewed designs that meet the design requirements shall be at the discretion of the Owner.

References

1. ASTM F1216-16 *Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing of a Resin-Impregnated Tube APPENDIX X-1 DESIGN CONSIDERATIONS*
2. WRc (UK) Sewerage Rehabilitation Manual (now Sewer Risk Management)
3. Network Rail's Specification for CCTV Inspection of Drainage by Mott MacDonald 2013.
4. American Pipeline Assessment and Certification Program (PACP) Grading System.
5. National Association of Sewer Service Companies (NASSCO) Cured-In-Place Pipe (CIPP) Installation – Performance Specification Guideline.
6. International Conference on Underground Infrastructure Research (Canada) – Trenchless technology Research Colloquium 2001 – Workshop Liner Design – International Design Method Comparison Report – Olivier Thepot (Page 9 Section 2.3)

Annex C
(informative)

Items that may be needed to cover measurement and payment

The following may have to be addressed in the Pricing Data section of the project document when compiling that section for a particular project (refer to Annex D of SANS 10403: 2003).

At present the SANS 2001 series of standards are being prepared to replace the existing SANS 1200 series of specifications.

It is planned that for measurement and payment SANS 2001 will adopt the Third Edition of the Civil Engineering Standard Method of Measurement (CESMM3) published by the UK Institution of Civil Engineers (ICE) or a South African version thereof.

Until SANS 2001 is fully completed and introduced, it will be necessary to refer back to the SANS 1200 measurement and payment clauses and/or the following particular measurement and payment clauses. This also applies to the SASTT-TS series of standards.

The following are measurement and payment clauses that would be suitable for such reference:

1. MEASUREMENT AND PAYMENT

1.1 General

CCTV inspections, pipe cleaning, point repairs, overpumping, manhole opening and repairs, and any other work shall be measured and paid separately.

1.2 Scheduled items

MEASUREMENT AND PAYMENT

1.2.1 **<u>Pay Item</u>** **<u>Unit</u>**

Supply and install cured in place pipe liner m

Liner outside diameter ########## mm
Depth to invert category ########## m
Liner thickness .... mm
Inverted or pulled in ……………………..
Reinforced or unreinforced ……………..

(###### to be scheduled in tender document)
(………. to be inserted by tenderer)

The Cured in Place Pipe liner shall be measured on actual length of lined pipeline including manhole benching. Separate items shall be scheduled for each nominal diameter of liner and depth category. The price tendered and paid shall include full compensation for the cost of design, manufacturing, supply and installing the liner, curing, sealing at the manholes, insertion pits, final cleaning of pipelines, CCTV inspections, testing, safety measures, all supervision, labour, materials, transport, equipment and incidentals required to line the host pipeline. In the case of pulled in liners the rate shall include the supply and installation of a sliding foil.

<Seventy-five percent (75%)> of the payment for Cured in Place Pipe linings will be made once the liner has been successfully installed and inspected by CCTV. The remaining <twenty-five percent (25%)> of the payment will be made once the liner has passed all tests and has been accepted.

<percentage to be determined by Owner>

1.2.2 **Pay Item** **Unit**

Supply and install preliner - outside diameter ########## m

(###### to be scheduled in tender document)

The preliner shall be measured on actual length of lined pipeline. Separate items shall be scheduled for each nominal diameter of preliner. The price tendered and paid shall include full compensation for the cost of manufacturing, supply and installing the preliner as part of the liner installation process, safety measures, all supervision, labour, materials, transport, equipment and incidentals required to install the preliner.

1.2.3 **Pay Item** **Unit**

Supply and install calibration hose m

Hose outside diameter ########## mm
Depth to invert category ########## m
Liner thickness .... mm

(###### to be scheduled in tender document)
(………. to be inserted by tenderer)

The calibration hose shall be measured on actual length of lined pipeline. Separate items shall be scheduled for each nominal diameter of hose and depth category. The price tendered and paid shall include full compensation for the cost of manufacturing, supply and installing the hose as part of the liner installation process, safety measures, all supervision, labour, materials, transport, equipment and incidentals required to install the hose and remove afterwards.

1.2.4 **Pay Item** **Unit**

Service reconnection No

The service reconnection shall be paid for each pipe connection that is re-established by cutting a hole in the Cured in Place Pipe liner.

The price tendered and paid shall include full compensation for the cost of providing and operating all equipment including robotic cutters, recovering and removal of the waste materials and the associated CCTV camera inspections.